

TITLE OF THE INVENTION

SEMICONDUCTOR DEVICE HAVING FERROELECTRIC FILM AND  
MANUFACTURING METHOD THEREOF

BACKGROUND OF THE INVENTION

5           1. Field of the Invention

This invention relates to a semiconductor device having a ferroelectric film and a manufacturing method thereof and more particularly to a ferroelectric capacitor in a ferroelectric memory (FeRAM).

10           2. Description of the Related Art

Recently, as semiconductor memories, volatile DRAMs (Dynamic RAMs), SRAMs (Static RAMs), nonvolatile MROMs (Mask ROMs), Flash EEPROMs and ferroelectric memories (FeRAMs) are on the market.

15           The ferroelectric memory stores binary data in a nonvolatile fashion depending on the magnitude of two different residual dielectric polarizations of a ferroelectric capacitor based on the hysteresis characteristic which is one of the characteristics of a  
20           ferroelectric material.

Like in the case of a DRAM, some of the memory cells which configure a conventional ferroelectric memory are each configured by serially connecting a capacitor and a transistor. In such a ferroelectric  
25           memory, a ferroelectric capacitor can be formed by performing a photolithography process once. That is, an upper electrode and lower electrode of the

ferroelectric capacitor and a ferroelectric film  
between the upper and lower electrodes can be formed by  
performing a photolithography process once. The  
photolithography process indicates a process in which a  
5 resist film is formed, a resist pattern is formed by  
exposure and development and a to-be-coated film under  
the resist pattern is formed by use of the resist  
pattern.

Further, some other memory cells which configure  
10 another conventional ferroelectric memory have the  
following configuration.

A series connected TC unit type ferroelectric  
memory comprises series connected memory cells each  
having a transistor (T) having a source and a drain and  
15 a ferroelectric capacitor (C) inbetween the source and  
the drain.

FIG. 1A is a plan view of a ferroelectric  
capacitor in the conventional series connected TC unit  
type ferroelectric memory and FIG. 1B is a cross  
20 sectional view showing the structure of the  
ferroelectric capacitor.

As shown in FIG. 1B, source and drain diffusion  
layers 102 are separately formed in the surface region  
of a semiconductor substrate 101. A gate electrode 104  
25 of each cell transistor is formed over a portion of the  
semiconductor substrate 101 which lies between the  
source and drain diffusion layers 102 with a gate

insulating film 103 interposed between the portion of the semiconductor substrate 101 and the gate electrode 104.

5       An interlayer insulating film 105 is formed on the semiconductor substrate 101. A lower electrode 106, a ferroelectric film 107 and upper electrodes 108 which configure the ferroelectric capacitors are formed in this order in the interlayer insulating film 105.

10       The ferroelectric film 107 is formed on the lower electrode 106. Two separated upper electrodes 108 are formed on the ferroelectric film 107. Further, the lower electrode 106 is connected to a corresponding one of the source and drain diffusion layers 102 and one of the two upper electrode 108 is connected to the other  
15       of the source and drain diffusion layers 102.

      Thus, the ferroelectric capacitor of the ferroelectric memory has a structure in which one pair of upper electrodes 108 are disposed over one lower electrode 106.

20       In the series connected TC unit type ferroelectric memory as shown in FIGS. 1A and 1B, since a structure in which one pair of upper electrodes 108 are disposed over one lower electrode 106 is formed as described before, it is necessary to perform the photolithography  
25       process at least twice in order to form a capacitor having one lower electrode 106 and one pair of upper electrodes 108.

More specifically, the following process is performed. In the conventional series connected TC unit type ferroelectric memory, upper electrodes 108 are formed by use of a first mask. Then, after a  
5 second mask is formed to protect each pair of upper electrodes 108, ferroelectric films 107 and lower electrodes 106 are formed.

In the process using two mask steps, misalignment occurs between the first and second masks. Therefore,  
10 as shown in FIG. 1A, it is necessary to provide a margin of a misalignment portion 109 between the upper electrode 108 formed by use of the first mask and the lower electrode 106 formed by use of the second mask. As a result, the cell area of the capacitor is  
15 increased by an amount corresponding to the misalignment portion and there occurs a problem that the occupied area on the chip of the ferroelectric memory having the capacitors incorporated therein is increased.

20 BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention, there is provided a semiconductor device comprising a first semiconductor region formed in a surface region of a semiconductor substrate; a second semiconductor  
25 region formed separately from the first semiconductor region in a surface region of the semiconductor substrate; a gate insulating film formed on a portion

of the semiconductor substrate which lies between the first semiconductor region and the second semiconductor region; a gate electrode formed on the gate insulating film; an interlayer insulating film formed on the semiconductor substrate to cover the first semiconductor region, second semiconductor region and gate electrode; first and second lower electrodes formed on the interlayer insulating film; a first contact plug formed in the interlayer insulating film in contact with the first lower electrode; a second contact plug formed in the interlayer insulating film separately from the first contact plug and in contact with the second lower electrode; a first ferroelectric film formed on the first lower electrode; a first upper electrode formed on the first ferroelectric film; a second ferroelectric film formed on the second lower electrode; and a second upper electrode formed on the second ferroelectric film.

According to another aspect of the present invention, there is provided a semiconductor device manufacturing method comprising forming a gate electrode over a semiconductor substrate with a gate insulating film interposed between the semiconductor substrate and the gate electrode; forming source and drain diffusion layers on a surface of the semiconductor substrate on both sides of the gate electrode; forming a first interlayer insulating film

on the semiconductor substrate to cover the gate  
electrode, source and drain diffusion layers; forming a  
buried interconnection and a first contact plug which  
extends from a portion of the buried interconnection to  
5 one of the source diffusion layer and the drain  
diffusion layer in the first interlayer insulating film  
which lies on the source and drain diffusion layers;  
forming a second interlayer insulating film on the  
first interlayer insulating film and on the buried  
10 interconnection containing the first contact plug;  
forming a pair of second and third contact plugs which  
extend from the surface of the second interlayer  
insulating film to the buried interconnection in the  
second interlayer insulating film formed on the buried  
15 interconnection; and forming a first ferroelectric  
capacitor by sequentially laminating a first lower  
electrode, first ferroelectric film and first upper  
electrode in this order on the second contact plug and  
forming a second ferroelectric capacitor by  
20 sequentially laminating a second lower electrode,  
second ferroelectric film and second upper electrode in  
this order on the third contact plug.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1A is a plan view of ferroelectric capacitors  
25 of the conventional series connected TC unit type  
ferroelectric memory;

FIG. 1B is a cross sectional view showing the

structure of the ferroelectric capacitors;

FIG. 2A is a layout view of ferroelectric capacitors of a ferroelectric memory according to a first embodiment of this invention;

5           FIG. 2B is a cross sectional view showing the structure of the ferroelectric memory of the first embodiment;

FIG. 3 is a cross sectional view showing a first step of a manufacturing method of the ferroelectric  
10           memory of the first embodiment;

FIG. 4 is a cross sectional view showing a second step of the manufacturing method of the ferroelectric memory of the first embodiment;

FIGS. 5A and 5B are cross sectional views showing  
15           a third step of the manufacturing method of the ferroelectric memory of the first embodiment;

FIGS. 6A and 6B are cross sectional views showing a different step as the third step of the manufacturing method of the ferroelectric memory of the first  
20           embodiment;

FIGS. 7A and 7B are cross sectional views showing a fourth step of the manufacturing method of the ferroelectric memory of the first embodiment;

FIG. 8A is a layout view of a ferroelectric  
25           capacitor formed by the manufacturing method according to the first embodiment;

FIG. 8B is a layout view of the conventional

ferroelectric capacitor;

FIG. 9 is a cross sectional view showing the structure of a ferroelectric memory according to a second embodiment of this invention;

5        FIG. 10 is a cross sectional view showing the structure of the ferroelectric memory as a first modification of the second embodiment; and

FIG. 11 is a cross sectional view showing the structure of the ferroelectric memory as a second  
10        modification of the second embodiment.

#### DETAILED DESCRIPTION OF THE INVENTION

There will now be described embodiments of this invention with reference to the accompanying drawings. In the following explanation, common portions in the  
15        drawings are denoted by the same reference symbols.

A semiconductor device described in this specification is a ferroelectric memory having cell transistors and ferroelectric capacitors. The ferroelectric memory is a series connected TC unit type  
20        ferroelectric memory that comprises series connected memory cells each having a transistor (T) having a source and a drain and a ferroelectric capacitor (C) inbetween the source and the drain.

#### [First Embodiment]

25        First, a ferroelectric memory according to a first embodiment of this invention and a manufacturing method thereof are explained.



FIG. 2A is a layout view of ferroelectric capacitors of the ferroelectric memory according to the first embodiment. FIG. 2B is a cross sectional view showing the structure of the ferroelectric memory.

5           As shown in FIG. 2B, source and drain diffusion layers 12 are separately formed in the surface region of a semiconductor substrate 11. Each of gate insulating films 13 is formed on a portion of the semiconductor substrate 11 which lies between the  
10           source and drain diffusion layers 12. Gate electrodes 14 of cell transistors are formed on the respective gate insulating films 13.

          An interlayer insulating film 15 is formed on the semiconductor substrate 11 to cover the gate electrodes  
15           14. Interlayer insulating films 16 and 17 are sequentially formed on the interlayer insulating film 15. In the interlayer insulating film 17 formed on the interlayer insulating film 16, lower electrodes 18A and 18B, ferroelectric films 19A and 19B and upper  
20           electrodes 20A and 20B which configure first and second ferroelectric capacitors are formed in this order. The first ferroelectric capacitor and the second ferroelectric capacitor configure one pair of  
25           ferroelectric capacitors in the series connected TC unit type ferroelectric memory. As the lower electrode, a film containing Ir, IrOx, Pt or TiN is used, for example. As the ferroelectric film, for

example, a PZT film is used, and as the upper electrode, a film containing Pt, Ir or IrOx is used, for example.

5 In portions of the interlayer insulating film 16 which lie under the lower electrodes 18A, contact plugs 21A are formed in contact with the lower electrodes 18A. In portions of the interlayer insulating film 16 which lie under the lower electrodes 18B, contact plugs 21B are formed in contact with the lower electrodes  
10 18B. Further, in portions of the interlayer insulating film 15 which lie under the contact plugs 21A and 21B, buried interconnections 22 each of which is connected to both of the corresponding contact plugs 21A and 21B are formed. In portions of the interlayer insulating  
15 film 15 which lie under the buried interconnections 22, contact plugs 23 respectively connected to the buried interconnections 22 are formed. Each of the contact plugs 23 is electrically connected to one of the source and drain diffusion layers 12.

20 That is, the lower electrode 18A among one pair of the lower electrodes 18A and 18B in one pair of ferroelectric capacitors is electrically connected to the diffusion layer 12 via a current passage which is configured by the contact plug 21A, buried inter-  
25 connection 22 and contact plug 23. Likewise, the lower electrode 18B is electrically connected to the diffusion layer 12 via a current passage which is

configured by the contact plug 21B, buried inter-connection 22 and contact plug 23. For example, tungsten (W) or polysilicon is used to form the contact plugs 21A, 21B, 23 and buried interconnections 22.

5           Further, in portions of the interlayer insulating film 17 which lie on the upper electrodes 20A, contact plugs 24A are formed and interconnections 25A are formed on the respective contact plugs 24A. In portions of the interlayer insulating film 17 which lie  
10           on the upper electrodes 20B, contact plugs 24B are formed and interconnections 25B are formed on the respective contact plugs 24B.

          In portions of the interlayer insulating films 17, 16, 15 which lie between the interconnections 25B and  
15           corresponding diffusion layers 12, contact plugs 26 are respectively formed and each of the interconnections 25B is electrically connected to a corresponding one of the diffusion layers 12 via the contact plug 26.  
          Further, each of the interconnections 25B is connected  
20           to an upper electrode 27A of an adjacent ferroelectric capacitor via a contact plug 28A. For example, Al, Cu or an alloy of Al and Cu is used to form the contact plugs 24A, 24B, 26, 28A and interconnections 25A and 25B.

25           In the ferroelectric memory of the first embodiment, the paired lower electrodes 18A and 18B connected to the same diffusion layer 12 are separately

formed. Further, the contact plugs 21A and 21B respectively connected to the paired lower electrodes 18A, 18B are also separately formed.

5 In the ferroelectric capacitor with the above structure, the upper electrodes 20A and 20B, ferroelectric films 19A and 19B and lower electrodes 18A and 18B can be formed by performing the lithography process using one mask step only. Therefore, it becomes unnecessary to provide a misalignment margin  
10 between the upper and lower electrodes, and as shown in FIG. 2A, the distance between the outer periphery of the upper electrode 18A and the outer periphery of the lower electrode 20A can be minimized. As a result, an area required for forming the ferroelectric capacitor  
15 can be reduced.

Next, the manufacturing method of the ferroelectric memory of the first embodiment is explained.

FIG. 3 to FIG. 7A, FIG. 7B are cross sectional views showing the steps of the manufacturing method of  
20 the ferroelectric memory.

For example, a silicon oxide film is formed on a semiconductor substrate 11 and a polysilicon film is formed on the silicon oxide film. Then, as shown in FIG. 3, the silicon oxide film and polysilicon film are  
25 patterned to form gate insulating films 13 formed of the silicon oxide film and gate electrodes 14 formed of the polysilicon film on the semiconductor substrate 11.

After this, an impurity ion-implantation process is performed with the gate electrodes 14 used as a mask to form diffusion layers 12 which are drain or source regions in the surface region of the semiconductor substrate 11 on both sides of each of the gate electrodes 14.

Next, an interlayer insulating film 15 is formed on the semiconductor substrate 11 to cover the gate electrodes 14 and diffusion layers 12. Then, the interlayer insulating film 15 is planarized by a CMP method. After this, grooves for interconnections are formed in portions of the interlayer insulating film 15 which lie above the diffusion layers 12 by an RIE method, for example. Further, holes are formed in the central portions of the respective interconnection grooves to reach the respective diffusion layers 12. In this case, the holes are formed after the interconnection grooves are formed, but it is also possible to first form the holes and then form the interconnection grooves.

Next, for example, a plug material of tungsten (W) or polysilicon is deposited on the interlayer insulating film 15 having the interconnection grooves and holes formed therein. Then, the plug material on the interlayer insulating film 15 is made flat by the CMP method. As a result, the plug material is buried in the interconnection grooves and holes to reach the

diffusion layers 12 so as to form buried interconnections 22 in the interconnection grooves and form contact plugs 23 in the holes.

5       Next, an interlayer insulating film 16 is formed on the buried interconnections 22 and interlayer insulating film 15. Further, in portions of the interlayer insulating film 16 which lie on each of the buried interconnections 22, a pair of holes are formed. Then, a plug material of tungsten (W) or polysilicon is  
10       deposited on the interlayer insulating film 16 having the paired holes formed therein. Then, the plug material on the interlayer insulating film 16 is planarized by the CMP method. As a result, the plug material is buried in the holes to reach the buried  
15       interconnections 22 so that contact plugs 21A and 21B can be formed.

After this, as shown in FIG. 4, films 18, 19 and 20 used to respectively configure lower electrodes, ferroelectric films and upper electrodes which  
20       configure ferroelectric capacitors are formed in this order on the structure shown in FIG. 3. In this case, as a material of the film used to form the lower electrodes, a material which prevents oxygen generated when the ferroelectric film is crystallized from  
25       entering the plug is used. The ferroelectric film is crystallized in an oxygen atmosphere at 600°C for one minute by using for example RTA (rapid thermal

annealing). As described before, as the lower electrode, a film containing Ir, IrOx, Pt or TiN is used, for example. Further, as the ferroelectric film, for example, a PZT film is used, and as the upper electrode, a film containing Pt, Ir or IrOx is used, for example.

Next, an aluminum oxide film 30 is deposited to a film thickness of approx. 100Å on the film 20 which will be used to form the upper electrodes by use of a sputtering method, for example. Then, the aluminum oxide film 30 is annealed in an oxygen atmosphere at 400°C so as to be sufficiently oxidized and insulated. Further, a plasma oxide film 31 is formed on the aluminum oxide film 30 by use of a plasma CVD method. The aluminum oxide film 30 is a film which enhances the adhesion between the film 20 used to form the upper electrodes and the plasma oxide film 31 and has the effect that damage caused on the film 20 used to form the upper electrodes when the plasma oxide film 31 is deposited is suppressed. The plasma oxide film 31 is used as a mask when the ferroelectric capacitors, that is, lower electrodes, ferroelectric films and upper electrodes are formed.

Then, a photoresist pattern is formed so that a pair of ferroelectric capacitors can be formed on each pair of contact plugs 21A and 21B. The plasma oxide film 31 is processed by use of the photoresist pattern.

After this, the photoresist pattern is removed by an  
ashing process. Then, the plasma oxide film 31 is used  
as a mask to form the upper electrodes 20A and 20B,  
ferroelectric films 19A and 19B, and lower electrodes  
5 18A and 18B by use of Ar/Cl<sub>2</sub>-series gas, for example,  
as shown in FIG. 5B. In this case, the etching rate of  
the plasma oxide film 31 which is a mask can be  
minimized by adding oxygen to the above gas and the  
selective ratio thereof with a capacitor material  
10 (upper electrode, ferroelectric film, lower electrode)  
can be increased.

In the paired capacitors formed by the above  
forming step, the lower electrodes 18A and 18B may be  
connected to each other. Thus the paired capacitors  
15 operate as is desired, because the paired lower  
electrodes 18A and 18B are electrically connected via  
the contact plugs 21A and 21B and buried inter-  
connection 22.

That is, as shown in FIG. 6A, a structure in which  
20 a lower electrode 18C is not divided, upper electrodes  
20AA and 20BB are separated from each other, and  
ferroelectric films 19AA and 19BB are separated from  
each other may be used. Further, as shown in FIG. 6B,  
a structure in which a lower electrode 18C is not  
25 divided, a ferroelectric film 19C is not divided and  
only upper electrodes 20AA and 20BB are separated from  
each other may be used.



Next, as shown in FIG. 7A, an aluminum oxide film 32 is formed to a film thickness of approx. 100Å on the upper surfaces of the upper electrodes 20A, on the side surfaces of the ferroelectric capacitors formed of the upper electrodes 20A, ferroelectric films 19A and lower electrodes 18A and on the interlayer insulating film 16 after the plasma oxide films 31 and aluminum oxide films 30 on the upper electrodes are removed. The aluminum oxide film 32 has the effect that oxygen is prevented from entering the contact plugs 21A and 21B and oxidation of the contact plugs 21A and 21B is suppressed in an oxygen high-temperature recovery annealing step performed after the present step and damage caused when an interlayer insulating film 17 is deposited on the ferroelectric capacitors is suppressed.

Next, the interlayer insulating film 17 is deposited on the aluminum oxide film 32. Then, the surface of the interlayer insulating film 17 is planarized by the CMP method. As shown in FIG. 7B, an aluminum oxide film 33 may be formed in the interlayer insulating film 17 on the aluminum oxide film 32 when required. If the aluminum oxide film 33 is formed, occurrence of damage caused in the multi-layered interconnection forming step later performed can be prevented. In the drawings other than FIGS. 7A and 7B, the aluminum oxide films 32 and 33 are omitted.

Next, holes reaching the upper electrodes 20A and 20B and holes reaching the diffusion layers 12 are formed in the interlayer insulating film 17. Further, interconnection grooves connected to the above holes are formed in the interlayer insulating film 17. Then, an oxygen high-temperature recovery annealing step is performed. After this, a TiN film is formed in the holes and interconnection grooves and on the interlayer insulating film 17. Al, Cu or an alloy of Al and Cu is deposited on the TiN film to fill the holes and interconnection grooves. Then, the interlayer insulating film 17 is planarized by the CMP method. As a result, as shown in FIG. 2B, contact plugs 24A, 24B, 26, and buried interconnections 25A and 25B are formed.

The layout diagram of the ferroelectric capacitor formed by the above manufacturing method is shown in FIG. 8A. Further, the layout diagram of the conventional ferroelectric capacitor is shown in FIG. 8B. It is clearly seen from FIGS. 8A and 8B that the area of the capacitor in the first embodiment is smaller than the area of the conventional capacitor. That is, the outer shape size of the lower electrodes 18A and 18B of the capacitor in the first embodiment can be made smaller than the outer shape size of the conventional lower electrode 106. This is because it is unnecessary to set a misalignment margin between the upper and lower electrodes since the upper and lower

electrodes of the capacitor in the first embodiment are formed by the same lithography process. Further, the distance between the cell transistors can be made small by reducing the area of the ferroelectric capacitor.

5 As a result, the area of the ferroelectric memory in which a plurality of ferroelectric capacitors and cell transistors are formed can be reduced.

Further, strictly speaking, in the capacitor structure of the conventional series connected TC unit  
10 type ferroelectric memory, it is impossible to symmetrically form paired capacitors if the upper and lower electrodes are misaligned, but in the first embodiment, capacitors with exactly the same structure can be formed.

15 [Second Embodiment]

Next, a ferroelectric memory according to a second embodiment of this invention is explained. The contact plugs which electrically connect the diffusion layer 12 to one pair of lower electrodes 18A and 18B in the  
20 configuration of the first embodiment shown in FIG. 2A are formed into a single contact plug, side wall insulating films are formed on the side wall surfaces of the gate electrode of each cell transistor and a cap insulating film is formed on the upper surface of each  
25 gate electrode.

FIG. 9 is a cross sectional view showing the structure of the ferroelectric memory according to the

second embodiment.

As shown in FIG. 9, source and drain diffusion layers 12 are separately formed in the surface region of a semiconductor substrate 11. Gate insulating films 13 are each formed on a portion of the semiconductor substrate 11 which lies between the source and drain diffusion layers 12. Gate electrodes 14 of cell transistors are formed on the respective gate insulating films 13.

Side wall insulating films 34 are formed on the side wall surfaces of each gate electrodes 14. Further, a cap insulating film 35 is formed on the upper surface of each gate electrodes 14. An interlayer insulating film 15 is formed on the semiconductor substrate 11 to cover the diffusion layers 12 and gate electrodes 14. Pairs of ferroelectric capacitors each pair including first and second ferroelectric capacitors are formed on the interlayer insulating film 15. That is, lower electrodes 18A, ferroelectric films 19A and upper electrodes 20A are sequentially formed in this order from the bottom on the interlayer insulating film 15. Each of the first ferroelectric capacitors is configured by the lower electrode 18A, ferroelectric film 19A and upper electrode 20A. Likewise, lower electrodes 18B, ferroelectric films 19B and upper electrodes 20B are sequentially formed in this order

from the bottom on the interlayer insulating film 15. Each of the second ferroelectric capacitors is configured by the lower electrode 18B, ferroelectric film 19B and upper electrode 20B.

5           Contact plugs 36 are each formed in a portion of the interlayer insulating film 15 which lies between a corresponding one of the diffusion layers 12 and a corresponding one pair of the lower electrodes 18A and 18B. The contact plug 36 electrically connects the  
10           diffusion layer 12 to a corresponding one pair of the lower electrodes 18A and 18B. Further, a portion of the contact plug 36 overlaps the cap insulating films 35 on the two gate electrodes 14 which are arranged on both sides of the diffusion layer 12. In the second  
15           embodiment, the two lower electrodes 18A and 18B of each pair of ferroelectric capacitors are completely separated.

          In the ferroelectric capacitor with the above structure, the upper electrodes 20A and 20B,  
20           ferroelectric films 19A and 19B and lower electrodes 18A and 18B can be formed by performing the photolithography process using one mask only. Therefore, it becomes unnecessary to provide a misalignment margin between the upper electrodes 20A  
25           and 20B and the lower electrodes 18A and 18B and the distance between the outer periphery of the upper electrode 20A and the outer periphery of the lower

electrode 18A can be made small. Likewise, the distance between the outer periphery of the upper electrode 20B and the outer periphery of the lower electrode 18B can be minimized. As a result, the area required for forming the ferroelectric capacitor can be reduced.

Further, since the area of the ferroelectric capacitor can be reduced, the distance between the cell transistors can be made small. As a result, the area of the ferroelectric memory in which a plurality of ferroelectric capacitors and cell transistors are formed can be reduced.

In the second embodiment, since the contact areas between the lower electrodes 18A and 18B and the contact plug 36 can be set large, the electrical resistivity of portions between the lower electrodes 18A and 18B and the contact plug 36 can be made low.

Further, as shown in FIG. 10, as a first modification of the second embodiment, a structure in which the two upper electrodes 20A and 20B are completely separated from each other, the ferroelectric films 19A, 19B are completely separated from each other and the lower electrode 18 is not divided in each pair of ferroelectric capacitors can be used.

As shown in FIG. 11, as a second modification of the second embodiment, a structure in which only the two upper electrodes 20A and 20B are separated from

each other and the ferroelectric film 19 and lower electrode 18 are not divided in each pair of ferroelectric capacitors can be used.

5 In the structures of the first and second modifications, the same effect as that of the second embodiment can be attained. In the second embodiment and in the first and second modifications, an example in which the contact plug 36 formed in contact with the diffusion layer 12 is formed in a self-alignment  
10 process with the gate electrodes 14 used as a mask is shown.

In the first and second embodiments and in the modifications of the second embodiment, the following material can be used. A material containing at least  
15 one of Pt, Ir, Ru and Sr can be used as the upper electrode. For example, an SRO electrode, RuOx electrode or the like can be used. Further, as the ferroelectric film, for example, PZT, PTO, or BTO or SBT with a layered-form perovskite structure may be  
20 used. As the lower electrode, a material containing at least one of Pt, Ir, Ru, Sr, Ti and Al can be used.

Further, each of the above embodiments can be independently carried out or the above embodiments can be adequately combined and carried out. In the above  
25 embodiments, inventive concepts of various stages are contained and the inventive concepts of various stages can be extracted by adequately combining a plurality of

constituents disclosed in the above embodiments.

As described above, according to the embodiments of this invention, a semiconductor device and a manufacturing method thereof can be provided in which  
5 the occupied area of each pair of capacitors on the chip can be made small by forming the paired capacitors by performing the photolithography process once.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore,  
10 the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as  
15 defined by the appended claims and their equivalents.